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WALNUT BLIGHT AND ITS CONTROL IN THE PACIFIC NORTHWEST

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INTRODUCTION

Walnut blight is the most widespread and destructive disease of the Persian (English) walnut in the Pacific Northwest. Losses from blight vary considerably. In some years the crop losses are on the whole relatively light, whereas in other seasons especially favorable for disease development losses ranging from 40 to 60 percent of the crop are not uncommon. Thus, it is estimated that in 1927 at least one-half of the walnut crop in the Pacific Northwest was destroyed by this disease, and in 1933 serious losses amounting in the aggregate to approximately 35 percent of the crop occurred.

The destructiveness of walnut blight in recent years has led to an insistent demand by walnut growers for the development of practical measures of control.

It is the purpose of this circular to give in a brief and nontechnical manner the most essential information now available on walnut blight and its control as worked out under conditions in western Oregon.

CAUSE OF THE DISEASE

Walnut blight is caused by a bacterium.[1] This micro-organism lives parasitically within the tissues of the plant, resulting in their eventual death. The walnut-blight bacterium is rodlike in shape with a flagellum or whiplike appendage at one end. It is so small that it can be seen only with the aid of a high-power microscope.

[1] *Phytomonas juglandis* (Pierce) Bergey et al. Synonyms: *Pseudomonas juglandis* Pierce; *Bacterium juglandis* (Pierce) E. F. Smith.

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DESCRIPTION

LEAF INFECTION

Walnut blight first appears in the spring on the young unfolding leaflets as small, yellowish-green "water-soaked" spots, which later turn reddish brown. The infections are generally noted first at the margins, where they often cause the leaflets to assume abnormal shapes due to the checking of growth in the infected areas (fig. 1, *A*). The veins, midribs (fig. 1, *B*), and petioles, as well as the expanded portions of the leaves between the veins (fig. 1, *C*), are all subject to blight infection. In the leaf blade the isolated infections are typically small, very seldom measuring more than one-eighth of an inch in the greatest dimension. Sometimes several or many infections may run together, however, and produce a relatively large brownish area. Walnut blight does not usually cause premature dropping of the leaves.

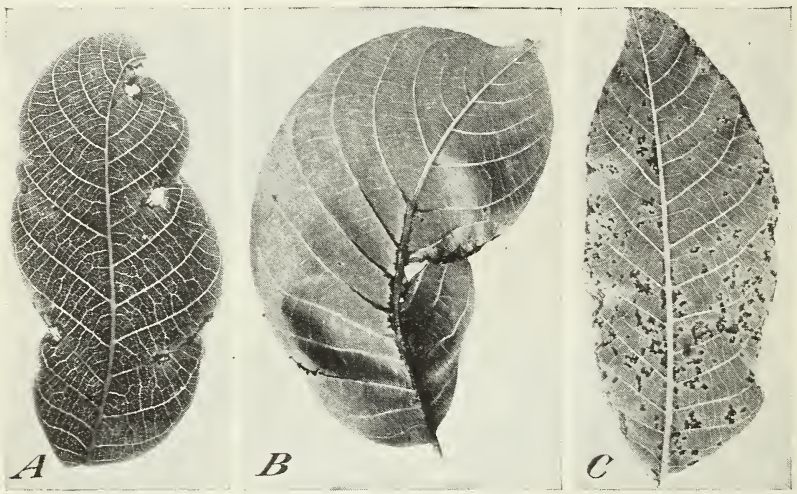

FIGURE 1.—Blight infections on walnut leaflets: *A*, Marginal leaf lesions; *B*, infections on midrib and veins of a leaflet; *C*, lesions in the expanded portion of a leaflet between the veins.

SHOOT INFECTION

Stems of young shoots of the new growth are also attacked by walnut blight. On the stems, blight infections manifest themselves as black, slightly depressed spots, which are typically surrounded by dark-green "water-soaked" zones in the early stages of parasitism (fig. 2, *A*). In some cases a blight infection may encircle the stem (fig. 2, *B*) and cause girdling and subsequent die-back of the shoot. Blight injuries to twigs may also occur at the base of blighted buds (fig. 2, *C*), around nut scars (fig. 2, *D*), or variously distributed on the surface of the young shoots. Twigs more than 1 year old are not typically attacked by blight.

BUD INFECTION

Leaf and catkin buds in the axils of leaves on new shoots are also susceptible to blight. Diseased buds eventually turn dark brown or black (fig. 3, *A* and *B*). Bud infection is a very serious aspect of walnut blight, for it has recently been found that the blight organism

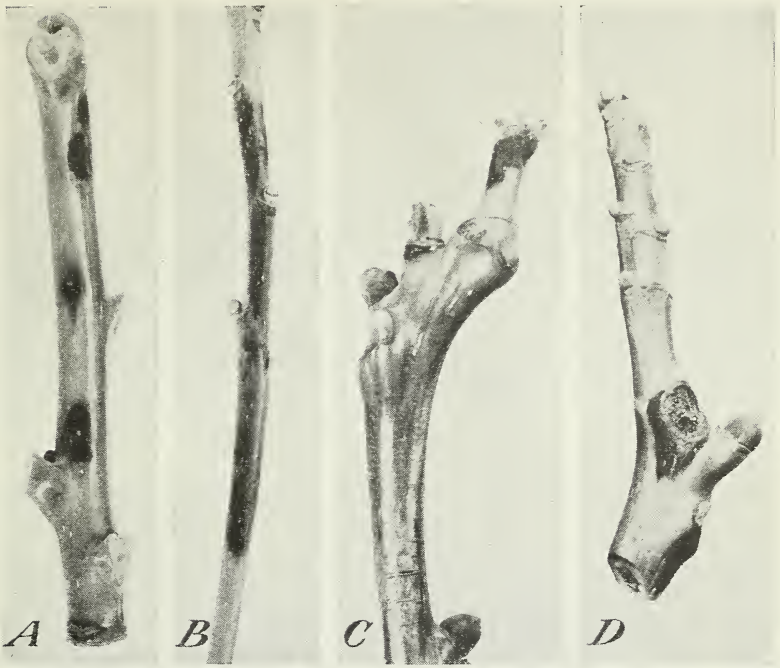

FIGURE 2.—Blight infections on walnut twigs: *A*, Lesions on stem of a walnut shoot; *B*, twig girdled by an infection; *C*, lesion on a twig at base of a blighted bud; *D*, infection about a nut scar.

FIGURE 3.—Blighted walnut buds that were infected in the spring and photographed in September of the same year: *A*, Infected catkin buds (*a*); *B*, diseased leaf bud (*a*).

is carried over winter, under western Oregon conditions, primarily in diseased buds. Bud blight results also in an economic loss, since many of the buds that are killed are potential nut-bearing buds.

NUT INFECTION

Blight is most serious and destructive on the nuts. Many nuts become infected at or shortly after the time of pollination. The first symptom of the disease on the young nuts consists of small "water-soaked" spots at the blossom end or on the sides of the nut. Spots on young nuts increase rapidly in size, become slightly depressed, and turn black (fig. 4, *A* and *B*). Nuts that are infected at or shortly after the time of blooming generally fail to mature, as the bacteria almost always gain access to the interior of the nut, where they cause the death of the developing kernel and result in premature dropping of the nut. Not all nuts that drop prematurely, however, are infected with blight. Some drop normally occurs as a result of a lack of pollination and faulty nutrition. Nuts that drop from either of these latter causes are free from black spots.

The interior tissues of the nut may be infected in some cases without the diseased condition being plainly visible from the exterior. In

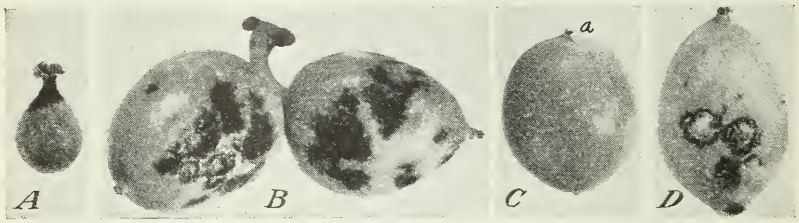

FIGURE 4.—Walnuts infected with blight: *A*, Infection at the blossom end of a young nut; *B*, lesions on the sides of nuts; *C*, nut infected internally with blight; from the outside the only evidence of infection is a slight depression in the tissues at the blossom end (*a*); *D*, a type of blight infection known as ring spot. Infections of this sort take place relatively late in the season and cease development fairly soon after infection occurs.

such cases the only evidence of infection is a slight depression in the tissues at the blossom end of the nut (fig. 4, *C*). If such a nut is cut open, however, the central tissues will generally be found to be badly discolored and shrunken. All nuts that are infected internally drop prematurely.

Under certain conditions a type of blight infection referred to by many growers as ring spot may occur in the fleshy husk of the nut. In this kind of infection a ring of blackened tissue encircles apparently normal green tissue, producing the effect shown in figure 4, *D*. These ring spots are infections that take place relatively late in the season. As a rule they are generally corked out by the host tissues and cease development relatively soon after infection occurs. Although this type of infection does not typically reach the shell of the nut, it may and often does result in a misshapen nut, due to the cessation of growth in the infected areas (fig. 5, *A*).

Whenever infection takes place after the shell begins to form, the blight lesions are usually confined to the fleshy husk. While such infections do not cause a loss of the nuts, they may result in misshapen nuts, which must be rejected from the top grades. In some cases of late-formed infections, however, the bacteria succeed in reaching the

shell, in which case the dead husk tissues usually stick to the shell at maturity, and the husk does not separate normally from the nut (fig. 5, *B*). An unbleachable brown stain is left on the shell when such blight spots are scraped off, thereby reducing the salability of the nut (fig. 5, *C*). After the nuts are approximately seven-eighths grown they are no longer susceptible to blight infection.

OVERWINTERING OF THE CAUSAL ORGANISM

Under western Oregon conditions, walnut blight is carried over winter primarily in diseased buds. Infections on twigs of previous years' growth and blighted nut mummies that hang on the trees from one season to the next may also carry the organism over winter, but these sources are not regarded as playing the most important part in overwintering the disease, owing to their relative scarcity when compared with the large number of blighted buds usually present in the trees.

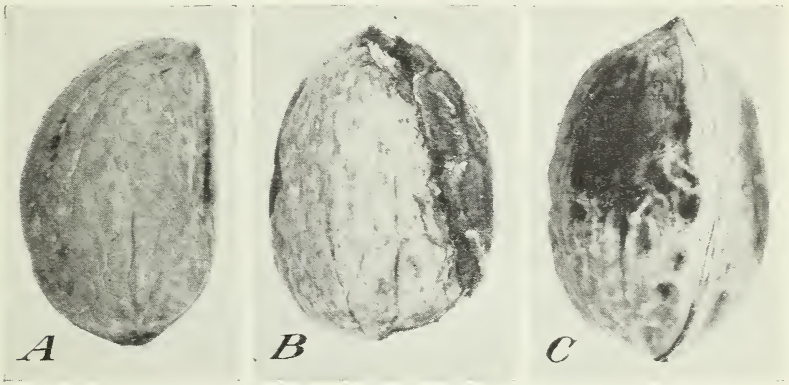

FIGURE 5.—Result of blight infections on shape and quality of walnuts: *A*, Misshapen nut caused by the presence of a blight infection in the fleshy husk; *B*, diseased part of husk adhering to the shell at maturity; *C*, brown stain left on the shell a ter the infected spot in the husk is scraped off.

DISSEMINATION OF THE DISEASE

Rain is the most important single agency concerned in the spread of walnut blight in Oregon. When prolonged and frequent rainy periods occur during the time when the nuts are young and hence most susceptible to this disease, blight epidemics result. Walnuts are susceptible to infection by blight from the time of blooming until the nuts are about seven-eighths grown. The most critical part of this period of susceptibility is the interval from the time of flowering to about 3 weeks thereafter. Nut infections occurring during this critical time practically always result in the destruction of the kernel and cause premature dropping of the nut.

As far as the writer's studies go, insects are not concerned to any significant extent, if at all, under Oregon conditions, in the spread of walnut blight.

CONTROL

Extensive experiments carried on over a number of years have demonstrated that the use of bordeaux mixture will give excellent con-

trol of walnut blight in orchards of uniform variety from grafted stock, provided a sufficient number of properly timed sprays are thoroughly applied.

Satisfactory control of walnut blight in seedling orchards, however, is much more difficult than in orchards from grafted stock. This is due largely to the fact that the great variation in the blooming periods of individual seedling trees makes it extremely difficult to time the spray applications properly. Results of experiments indicate, nevertheless, that it is possible to reduce substantially the number of blight infections in seedling orchards by applying a sufficient number of timely bordeaux-spray treatments. In order to time the applications properly in seedling plantings it is necessary to "spot" spray, that is, to apply the treatments to individual trees as they reach the proper stage of development. The extra time and expense involved in this sort of spray program tend to discourage the extensive use of bordeaux mixture in seedling orchards as a means of controlling blight except in relatively small acreages.

NUMBER OF SPRAY APPLICATIONS

Studies carried on by the writer over a period of 5 years indicate that no single program of spray treatments can be recommended which will be equally effective in all situations and under all conditions to be met with in the Pacific Northwest in different years. To secure satisfactory results the spray treatments must be applied frequently enough to keep the nuts covered with a protective coating of the spray mixture during the critical period for blight infection. Results of experiments in western Oregon indicate that, in most years, two properly timed applications may be expected to provide grafted orchards with adequate protection against blight. In seasons of unusually abundant or prolonged rainfall during the period when the nuts are subject to blight infection, additional applications may be required to control the disease satisfactorily.

TIMING OF APPLICATIONS

While the proper time of application will vary within certain limits to meet seasonal and local conditions, studies carried on in Oregon by the writer indicate that in an average season the spray treatments should be applied (1) just before the bulk of the female or pistillate flowers come into full bloom, and (2) immediately after the majority of the nut-bearing flowers have been pollinated.

The first treatment should not be applied too early in the prebloom stage of development. In general, the shorter the interval between the first spray treatment and the period of full bloom the greater will be the protection secured during the blooming period, which is a very critical period for blight infection. At the time for the first treatment most of the immature female flowers will be plainly visible on the new growth, but in only a very few early flowers will the blossom ends or stigmas be fully expanded. The young nuts at this stage of development will average about one-eighth of an inch in diameter, or roughly about the size of a very small grain of wheat (fig. 6, *A*). The first treatment should be completed before the bulk of the female flowers come into full bloom, in order to avoid any possibility that the spray may interfere with the fertilization of the nuts.

The second treatment should be given just as soon as it is reasonably certain that the majority of the female flowers have been pollinated, as indicated by the presence of tiny brown spots in the stigmas or blossom ends of the flowers. At this time the nuts will average three-sixteenths of an inch in diameter, or about the size of small peas (fig. 6, *B*). In an average season not more than 2 weeks will intervene between the first and second treatments. There may be a tendency on the part of some growers to wait until there is no doubt that all pollination is over before proceeding with the second spray application. If the interval between the first and second treatments is more than 2 weeks, poor results are likely to follow, especially if there should be a prolonged rainy period at the end of or just after the pollination period and before the application of the second or postbloom treatment. It is important, therefore, to apply this second treatment when it is reasonably certain that the bulk of the nut-bearing flowers have been pollinated.

If an abnormal amount of rain falls after bloom during the period when the nuts are susceptible to infection, a third treatment about 10 days after the second application may be necessary, in order to control blight satisfactorily (fig. 6, *C*).

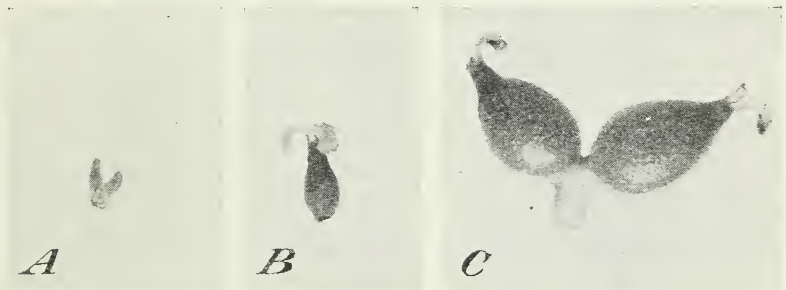

FIGURE 6.—Stages in the development of the nut at which bordeaux spray applications have been found effective in the control of blight: *A*, The prebloom stage of development, at which time the first spray treatment should be applied; *B*, the "pea" stage, immediately after bloom, at which time the second spray application should be made; *C*, the stage of development, 10 days to 2 weeks after bloom, at which time the third treatment should be made, provided the season is unusually rainy after bloom.

The extreme importance of timing the applications properly cannot be overemphasized, for the success of the spray program depends almost entirely upon this factor. Deferring the applications even for a few days after the proper stage of blossom or nut development has been reached may mean the difference between success and failure of the spray program.

STRENGTH OF SPRAY MIXTURE

Results of studies carried on over a 3-year period indicate that under western Oregon conditions bordeaux mixture 2-2-50 is practically as effective in the control of walnut blight as stronger mixtures, provided a sufficient number of treatments are given at the proper time.

THOROUGHNESS OF APPLICATION ESSENTIAL

If satisfactory control is to be secured, not only should the sprays be timed properly but they should be thoroughly applied. Spraying is not in any sense a cure for walnut blight; it serves only as a protection against infection. In order to secure adequate protection

from this disease, a film of spray must completely cover the nuts and foliage throughout the period of susceptibility.

SPREADERS

The use of some good spreading agent with bordeaux mixture will assist materially in a more even distribution of the spray and therefore is conducive to more complete coverage. Although there are a number of satisfactory commercial spreading agents on the market, certain kinds of home-made spreaders will give just as satisfactory results at a considerable saving in cost. A home-made spreader which has proved satisfactory may be prepared by using powdered skim milk. The formula for this spreader consists of:

Skim-milk powder	1 pound
Hydrated lime	2 tablespoons
Spray mixture	100 gallons

The hydrated lime should be put in a little water in a pail, the milk powder added, and the whole stirred vigorously before being added to the bordeaux mixture.

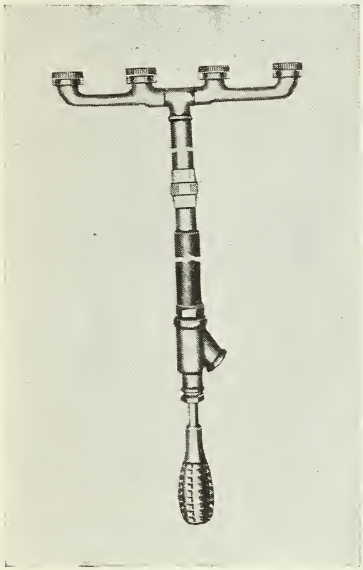

FIGURE 7.—A type of spray gun that has been found to be particularly effective under Oregon conditions in thoroughly coating the nuts and leaves with spray.

SPRAYING EQUIPMENT

The use of certain types of spray equipment makes the work of thorough spraying considerably easier and more certain of accomplishment without an undue waste of time and energy. The use of a power spray machine capable of developing from 400 to 500 pounds pressure per square inch and having a capacity of from 16 to 20 gallons of spray per minute results in a more thorough job of spraying in less time than if a machine of only limited power and capacity is employed. Certain types of spray guns and rods will also be found better adapted for spraying than others. The type that gives the best results is one that is capable of breaking up the spray into a fine cloud or mist and yet has considerable range. One of the most suitable spray rods on the market for walnut trees from 35 to 50 feet in height consists of a 10-foot aluminum rod of ¾-inch tubing with the cut-off in the basal casting (fig. 7). A row of four nozzles on a crossbar at the top of the rod breaks up the spray into a fine cloud or mist, the fineness depending on the size of the disks in the nozzles. This spray rod is capable of throwing a cloud of penetrating spray 30 to 40 feet high on a relatively calm day. The use of such a spray rod results not only in better penetration and coverage but also in considerable saving of liquid and time. With this rod faulty spraying due to inexperienced help is reduced to a minimum, since the operator cannot wrongly adjust the type of spray coming from the nozzle.

Improper spraying practices, such as keeping the gun continually open and throwing a coarse stream of spray, should be practically eliminated with this spray rod. It is particularly adapted to situations where inexperienced, transient help has to be depended upon to do the spraying. Most walnut trees in Oregon can be sprayed from the ground without resorting to towers. As the trees grow older and become taller it may be necessary, however, to use towers of various sorts in order to insure completeness of coverage in the tops of the trees

COST OF SPRAYING

The cost of spraying walnut trees with bordeaux mixture varies with the size of the trees, the amount of foliage present, and the type of equipment used. Cost records show that on the average the cost of spraying walnut trees approximately 45 feet in height will vary from 15 to 25 cents per tree for each application, depending largely on the amount of foliage present. When trees of this height are just beginning to leaf out, the total cost, based upon current (1934) prices, is about 15 cents per tree per application. When the trees are in full foliage, however, it costs approximately 25 cents to treat one tree with one application of spray. Smaller trees require less spray material and the cost will therefore be correspondingly less.

BENEFITS FROM SPRAYING

Yield records show that a definite increase in crop yield follows proper spraying with bordeaux mixture. Not only are there more nuts in properly sprayed orchards, but an increase in the quality of the yield is apparent, the percentage of culls and nuts with blight stains on the shells being appreciably reduced. Benefits from spraying for the control of walnut blight are apparently cumulative, as a gradual reduction in the amount of blight occurs from annual spraying over a period of years.

INJURIES ASSOCIATED WITH SPRAYING

Spray burn may and often does follow the application of bordeaux mixture to young walnut leaves that are not full grown. The margins or tips of young developing leaflets are the parts most generally affected. The injured areas turn brown and often drop out of the leaf tissues, leaving the affected leaflets misshapen or very ragged in appearance (fig. 8).

Young developing leaflets, which contain reddish pigments, are particularly susceptible to bordeaux injury. As the leaflets grow older and develop a normal green color they are no longer subject to spray burn. The new leaves developing on the growing shoots replace to a considerable extent the leaf area that has been injured, and the trees seem to recover in a comparatively short time. While no permanent damage to sprayed trees from leaf spray burn has been noted thus far, it is recognized that spray injury, even though slight, is not an advantage to the tree. Results of studies carried on in 1934 indicate that the use of either a summer oil emulsion or a highly refined light summer spray oil in the proportion of 1 gallon of oil to 100 gallons of spray mixture will reduce leaf burn appreciably without destroying the effectiveness of the spray. The oil should be

added to the bordeaux with the agitator going, after the spray mixture has been made.

There is some evidence to indicate that, under certain conditions, injury to the set of nuts may occur from spraying when the female flowers are in full bloom. In view of the possibility of thus interfering with the set, it is advisable to avoid the period when the bulk of the female flowers are in full bloom, in spraying for the control of walnut blight.

FIGURE 8.—Walnut leaves showing typical bordeaux-spray injury.

HOW TO MAKE BORDEAUX MIXTURE

Bordeaux mixture is made by mixing together very dilute solutions of copper sulphate (bluestone or blue vitriol) and lime (stone lime or quicklime). The amount of copper sulphate and lime will depend on the strength desired. The proportion of each ingredient used in any given strength is designated by a formula. For example, bordeaux 2-2-50 means that the mixture contains 2 pounds of copper sulphate and 2 pounds of lime in every 50 gallons of water. The

first figure in the formula represents the number of pounds of copper sulphate, the second figure the number of pounds of lime, and the third number the gallons of water.

If any considerable amount of bordeaux mixture is to be made, it is advisable to prepare concentrated stock solutions of both copper sulphate and lime from which the bordeaux mixture may be prepared as needed.

STOCK SOLUTIONS

Two or more watertight wooden barrels of 50 gallons capacity should be procured to hold the stock solutions. With a liquid measure of known capacity, calibrate the containers by pouring exactly 40 gallons of water into each barrel and marking the level of the water with brass or copper nails or with a small block of wood nailed on the inside of the barrel. When additional stock solutions are needed further measuring will be unnecessary. If any considerable acreage is to be sprayed, it is advisable to provide a larger number of barrels or several large wooden tanks holding from 100 to 200 gallons each.

To prepare the stock solution of copper sulphate, dissolve the requisite amount of copper sulphate in water in one or more containers as required, in the proportion of 1 pound of copper sulphate to 1 gallon of water. In the event that large quantities of stock solution are required, 2 pounds of copper sulphate may be dissolved in each gallon of water. Since a solution of copper sulphate is heavier than water, the copper sulphate crystals will go into solution much sooner if suspended in a loosely woven burlap sack near the top of the water. The time required for the copper sulphate to dissolve depends on the size of the crystals; large crystals take longer than smaller ones. A powdered form of copper sulphate which dissolves in a very short time, is on the market but this form is more expensive than the larger crystals. Copper sulphate crystals averaging about one-half inch through will generally take from 6 to 12 hours to dissolve in cold water. Hot water will expedite dissolving. If running water is available, the time required to dissolve the copper sulphate can be shortened considerably by allowing a stream of water from a hose to run over and through the suspended sack when the barrel is being filled with water. Remove the empty burlap sack after the crystals have all dissolved, and, if necessary, add sufficient water to bring the mixture up to the proportion of 1 pound of copper sulphate to 1 gallon of water.

To prepare the stock solution of lime, the following procedure is advised: Place the required amount of lime (stone lime or quicklime) in a calibrated watertight container, and add enough water to cover the lime. When it begins to boil, add more water and stir the mixture well so as to insure complete wetting of the lime. When the lime is completely slaked, add sufficient water to bring the mixture to the proportion of 1 pound of stone lime to 1 gallon of water. It is very important that the stone lime used in the preparation of the milk-of-lime solution be fresh and of high purity. Stone lime that has been allowed to air-slake is inert and is valueless in preparing bordeaux mixture.

Hydrated lime, if fresh and of high quality, may be substituted for quicklime if desired. It is often more convenient and equally satisfactory. When hydrated lime is used to make the stock solution

of lime it is advisable to allow the stock solution to stand at least several hours, preferably overnight, before using, in order to form a milk of lime equal in quality to that made by the use of stone lime. In order to make a stock solution of lime containing the equivalent of 1 pound of stone lime to 1 gallon of water it is necessary to use 1⅝ pounds of hydrated lime to every gallon of water. Thus, if 50 gallons of a pound-to-the-gallon stock solution of milk of lime is being prepared, 66 pounds of hydrated lime will be needed. Milk of lime made with a good grade of hydrated lime possesses the advantage of being practically free from insoluble lumps. Where time is an important factor this is a distinct advantage, since no difficulty should be experienced in straining the stock solution through the tank screen.

Before using lime from the stock solution, always stir thoroughly, as lime settles after a time, resulting in a more concentrated mixture at the bottom of the barrel than at the top.

THE FINAL MIXTURE

The duration of effectiveness of a bordeaux mixture spray will depend to a large extent on the manner in which the spray mixture has been prepared. There are several different methods of making bordeaux mixture, any one of which will make a satisfactory product. Regardless of the procedure followed, it is important that both the copper sulphate solution and the milk of lime be as dilute as possible when they are mixed. The following procedure will result in a very satisfactory product: Fill the spray tank about three-fourths full of water. Add the correct amount of milk of lime from the stock solution, screening the mixture through a 20-mesh tank screen to exclude any lumps that may be present. Start the agitator in the spray tank, and allow water to run into the tank by way of an inclined trough. Slowly pour the required quantity of the stock solution of copper sulphate into the running water in the trough, thereby diluting the copper sulphate solution considerably before it comes in contact with the diluted lime milk in the tank. If an oil or some spreading agent is to be used with the bordeaux mixture, it should be added to the spray mixture with the agitator going at this juncture. Finish filling the tank with water. The bordeaux mixture is now ready for use.

Bordeaux mixture should be applied immediately after it is prepared. If for some unexpected cause this is not feasible, it may be preserved for a few hours by the addition of one-eighth of an ounce of cane sugar for each pound of copper sulphate used in making the spray mixture. For example, in the preparation of 200 gallons of a 2-2-50 bordeaux mixture 8 pounds of copper sulphate are used; therefore 1 ounce ($8 \times \frac{1}{8}$) of sugar dissolved in a little water will be required to preserve 200 gallons of bordeaux mixture 2-2-50.

PRECAUTIONS

Under no circumstances should copper sulphate crystals and lime be mixed together and then dissolved, for such a preparation is practically worthless as a spray. Furthermore, never pour the undiluted stock solutions of copper sulphate and milk of lime together and dilute afterwards.

The stock solution of copper sulphate should never be prepared in iron barrels, nor should iron pails be used to transfer copper sulphate to the spray tank, since this chemical will corrode iron, thus injuring the value of the solution and destroying the containers. Enameled pails will be found satisfactory for use in measuring the copper sulphate solution and in transferring it to the spray tank.

To prolong the life of spray machinery and equipment it is advisable to rinse them with clean water after completing spraying operations for any one day. A thorough rinsing with water is particularly important before storing the equipment for the winter.

DUSTING NOT ADVISED

Dusts that have been used by the writer in experiments carried on so far have not given satisfactory control of walnut blight. The following dusts have been tried: Copper-lime dust (20 percent monohydrated copper sulphate and 80 percent hydrated lime), dehydrated bordeaux lime dust (1 part of a proprietary dehydrated bordeaux mixture, containing 12 percent metallic copper, and 2 parts of hydrated lime), 3 types of flotation sulphur dusts, and a proprietary gas-house colloidal dusting sulphur. Although a limited reduction in the amount of blight infection occurred from the use of certain of the dusts, none of them has given as good results as have the liquid bordeaux mixture sprays. At the present time, therefore, the use of these dusts for the control of walnut blight is not advised.

SUMMARY OF CONTROL PROGRAM

Cover the leaves and nuts with a thorough coating of bordeaux mixture spray (2-2-50 formula) as follows:

First application: Just before the bulk of the female or nut-bearing flowers come into full bloom (p. 6 and fig. 6, *A*). A summer oil emulsion or a highly refined light summer spray oil in the proportion of 1 gallon of oil to 100 gallons of the spray mixture may be added to this application of bordeaux mixture to reduce leaf burn.

Second application: Immediately after the majority of the female flowers have been pollinated and the nuts are about the size of small peas (p. 7 and fig. 6, *B*).

Third application: About 10 days after the second application, provided the season is unusually rainy after bloom (p. 7 and fig. 6, *C*).

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